Eur J Vasc Endovasc Surg (2023) 65, 811–817

Editor's Choice – Early Outcomes of a Novel Off the Shelf Preloaded Inner Branch Endograft for the Treatment of Complex Aortic Pathologies in the ItaliaN Branched Registry of E-nside EnDograft (INBREED)

Michele Piazza [a,*], Francesco Squizzato [a], Giovanni Pratesi [b], Yamume Tshomba [c], Andrea Gaggiano [d], Emanuele Gatta [e], Gioele Simonte [f], Gabriele Piffaretti [g], Paolo Frigatti [h], Gian Franco Veraldi [i], Roberto Silingardi [j], Michele Antonello [a], on behalf of the INBREED Investigators [†]

[a] Division of Vascular and Endovascular Surgery, Department of Cardiac, Thoracic, Vascular Sciences and Public Health, University of Padua, Padua, Italy
[b] Vascular and Endovascular Surgery Unit, Ospedale Policlinico San Martino, University of Genoa, Genoa, Italy
[c] Unit of Vascular Surgery, Fondazione Policlinico Universitario A. Gemelli I.R.C.C.S., Università Cattolica del Sacro Cuore, Rome, Italy
[d] Vascular and Endovascular Surgery Unit, Mauriziano Umberto I Hospital, Turin, Italy
[e] Vascular and Endovascular Surgery Unit, Ospedali Riuniti di Ancona, Ancona, Italy
[f] Unit of Vascular and Endovascular Surgery, Santa Maria della Misericordia Hospital, Perugia, Italy
[g] Vascular Surgery, Department of Medicine and Surgery, ASST Settelaghi University Teaching Hospital, University of Insubria School of Medicine, Varese, Italy
[h] Division of Vascular Surgery, Azienda Sanitaria Universitaria Friuli Centrale, S. Maria della Misericordia University Hospital of Udine, Udine, Italy
[i] Vascular Surgery, Integrated University Hospital of Verona, Verona, Italy
[j] Division of Vascular Surgery, University Hospital of Modena and Reggio Emilia, Baggiovara (MO), Italy

WHAT THIS PAPER ADDS

This is the first clinical multicentre study to analyse real world experience with a novel off the shelf pre-loaded inner branched endograft (E-nside). The excellent technical implantation safety and efficacy, as well as good 90 day outcomes, demonstrate that this endograft can be considered in the endovascular armamentarium as a valid option for the repair of thoraco-abdominal aortic pathologies. The study also provides a benchmark for comparison with future results obtained with other off the shelf or custom endografts in this field.

Objective: The aim of this study was to investigate the early outcomes of a novel off the shelf pre-loaded inner branched thoraco-abdominal endograft (E-nside) in the treatment of aortic pathologies.

Methods: Data from a physician initiated national multicentre registry on patients treated with the E-nside endograft, were prospectively collected and analysed. Pre-operative clinical and anatomical characteristics, procedural data, and early outcomes (90 days) were recorded in a dedicated electronic data capture system. The primary endpoint was technical success. Secondary endpoints were early mortality (90 days), procedural metrics, target vessel patency, endoleak rate, and major adverse events (MAEs) at 90 days.

Results: In total, 116 patients from 31 Italian centres were included. Mean ± standard deviation (SD) patient age was 73 ± 8 years and 76 (65.5%) were male. Aortic pathologies included degenerative aneurysm in 98 (84.5%), post-dissection aneurysm in five (4.3%), pseudoaneurysm in six (5.2%), penetrating aortic ulcer or intramural haematoma in four (3.4%), and subacute dissection in three (2.6%). Mean ± SD aneurysm diameter was 66 ± 17 mm; aneurysm extent was Crawford I – III in 55 (50.4%), IV in 21 (19.2%), pararenal in 29 (26.7%), and juxtarenal in four (3.7%). The procedure setting was urgent in 25 (21.5%) patients. Median procedural time was 240 minutes (interquartile range [IQR] 195, 303), with a median contrast volume of 175 mL (IQR 120, 235). The endograft's technical success rate was 98.2% and the 90 day mortality rate was 5.2% ($n = 6$; 2.1% for elective repair and 16% for urgent repair). The 90-days cumulative MAE rate was 24.1% ($n = 28$). At 90 days, there were 10 (2.3%) target vessel related events (nine occlusions and one type IC endoleak) and one type 1A endoleak requiring re-intervention.

Conclusion: In this real life, non-sponsored registry, the E-nside endograft was used for the treatment of a broad spectrum of aortic pathologies, including urgent cases and different anatomies. The results showed excellent technical implantation safety and efficacy, as well as early outcomes. Longer term follow up is needed to better define the clinical role of this novel endograft.

Keywords: Aortic aneurysm, Aortic dissection, Branched endovascular aortic repair, Endovascular repair, Multicentre study, Thoraco-abdominal aortic aneurysm

Article history: Received 21 September 2022, Accepted 27 February 2023, Available online 3 March 2023

[†] A list of the INBREED Investigators is included in Appendix A.

* Corresponding author. Vascular and Endovascular Surgery Division, Padua University, Department of Cardiac, Thoracic, Vascular Sciences and Public Health, Via Giustiniani, two – 35128 Padua, Italy.

E-mail address: mikpia79@hotmail.com (Michele Piazza).

https://doi.org/10.1016/j.ejvs.2023.02.076

INTRODUCTION

Complex abdominal and thoraco-abdominal aortic aneurysm repair has progressively evolved towards a minimally invasive endovascular approach. When anatomically suitable, the use of branched thoraco-abdominal endografts avoids highly invasive open surgery that carries a substantial risk of death and morbidity.[1–3]

In particular, off the shelf conformations carry the advantage of a readily available device that can be implanted in symptomatic or urgent cases, while custom made devices are specifically manufactured according to the patient's anatomy but, because of the variable manufacturing period, are generally used in elective cases.

The first standardised design of a multibranched thoraco-abdominal stent graft was proposed by Sweet *et al.* in 2008,[4] with clinical use in 2011. In 2012, the first off the shelf multibranched stent graft (Zenith T branch; Cook Medical, Bloomington, IN, USA) became available in Europe. Since then, several single and multicentre experiences have been published, describing excellent outcomes, both in elective and urgent settings.[5–9] The E-nside endograft (Artivion; Kennesaw, GA, USA) has received the "CE" mark, and became commercially available in 2020. This new device, derived from a custom made platform (Artivion E-xtra design custom made endograft),[10] provides several unique characteristics, including two possible different proximal and distal diameters, an exclusive inner branch design with antegrade orientation, and the presence of a dedicated pre-cannulated tube for each branch cuff. These adjunctive features may help to expand the anatomical feasibility of an endovascular approach, and improve procedural technical success.

To date, only theoretical studies or case reports focusing on this device have been published,[11] and no clinical outcomes are available in the literature.[12,13] The aim of this multicentre study was to evaluate device implantation safety and 90 days outcomes in real world practice.

METHODS

Study design

The ItaliaN Branch Registry of E-nside EnDograft (INBREED) is a physician initiated, non-sponsored prospective multicentre observational cohort registry. Decisions on indications, patient selection, surgical technique, and peri-operative care were not standardised and were left to each treating centre. Institutional Review Board and ethics committee approval were required (Ethic Committee for Clinical Experimentation, Padova: study ID 21175); each patient signed written consent for surgical treatment, anonymised data use, and follow up for scientific purposes. Data privacy was managed according to National Privacy Act. Preliminary results have been reported previously in part.[14]

Data collection and definitions

Anonymised data were entered by delegates from each participating centre. One centre (Vascular—Endovascular Surgery Division, University of Padua, Padua, Italy) was responsible for the electronic data capture system (RedCap),[15] checking the quality of the imputed data and performing the final analysis. A monitoring plan was implemented via audits every six months (a total of three for this study) and queries were applied for specific data errors (missing, incomplete, or unclear).

Demographics, clinical characteristics, operative data, and 90 day outcomes were collected. Aneurysm classification was based on the extent of aneurysmal disease, evaluated by computed tomography angiography (CTA) according to reporting standards.[3,16] Anatomical characteristics were also assessed on the pre-operative CTA. Each treating centre applied the current reporting standards for stroke and spinal cord ischaemia (SCI).[16] A post-operative CTA was obtained for all survivors within one month of the index procedure.

Operative techniques

The entire procedure steps have previously been reported in Zimmermann *et al.*,[13] and the graft design is described in Figure 1. According to the manufacturer's instructions for use (IFU), the device should land in a thoracic endograft. In cases with poor accesses, the use of a 26 F introducer sheath may be useful for safe advancement and facilitate adequate rotation of the graft for orientation. In the case of narrow aorta, it is possible to unsheathe it partially (down to the opening of the renal branches), to save space for navigation and target vessel (TV) cannulation. The polyamide tubes can be loaded with a 0.018 inch non-hydrophilic wire before or after deployment of the proximal end of the main graft. After deployment, each single guidewire can be pushed over the tube outside the top of the graft, in the descending thoracic aorta, and snared one at a time. At this point the tube can be removed, and the respective branch and TV can be sequentially bridged; once completed, the wire can be definitely removed.

Endpoints

The primary study endpoint was technical success (endograft related and branch related) according to current reporting standards.[16] The secondary endpoints were 90 day death, procedural metrics, successful use of the preloaded system (successful guidewire insertion, snare, and bridging stent deployment), bridging time (time from preloaded system cannulation to deployment of the bridging stent for each vessel), and 90 day major adverse events (MAEs) and TV instability.[16]

Statistical analysis

Results were reported as number and percentage for categorical variables, mean ± standard deviation, or median (interquartile range [IQR]) for continuous variables; these were compared with the Wilcoxon rank sum test or *t* test, as appropriate. The Pearson chi square and Fisher exact tests were used for analysis of categorical variables. A *p*

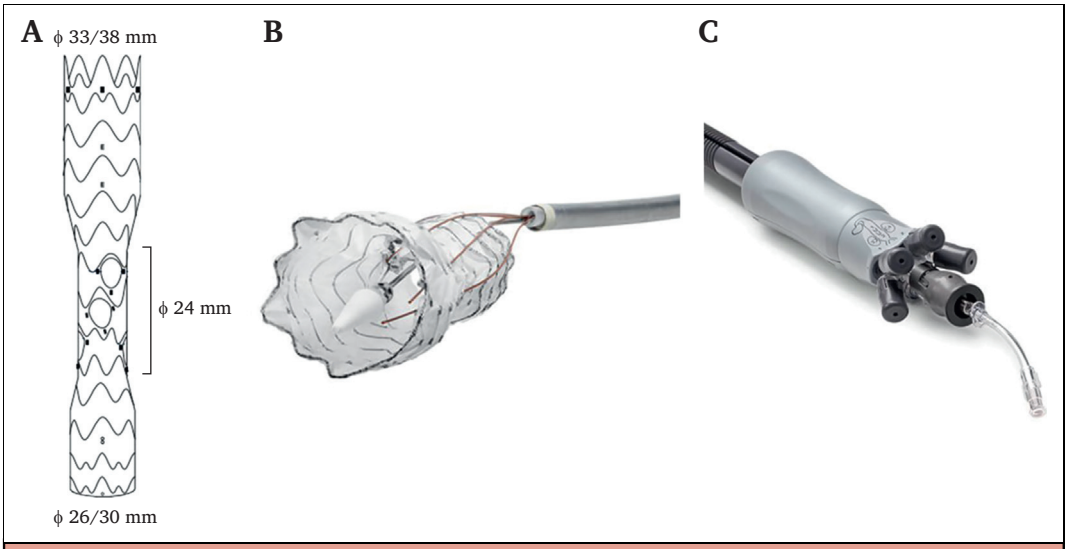

Figure 1. (A) E-nside graft design. It has a 24 F outer diameter delivery system. The inner branch diameter is 8 mm for the coeliac trunk and superior mesenteric artery, and 6 mm for the renal arteries; all four inner branches have a length of 2 cm with antegrade orientation and an enlarged oval shape outlet. (B) Picture of a partially deployed E-nside, showing the dedicated pre-cannulated tubes used for branch cannulation. (C) Detail of the ports used for 0.018 inch guidewire insertion for the cannulation of the endograft branches using the pre-loaded system.

value $<$ .050 was used to determine statistical significance. R 4.0 software (R Foundation for Statistical Computing, Vienna, Austria) was used.

RESULTS

Patient population

One hundred and sixteen patients were enrolled between June 2021 and September 2022 at 31 centres (mean 3.7 patients per centre; range 1 — 15), representing 69% of E-nside implanted nationwide in the same period. Five centres had eight or more cases and accounted for 48.3% (n = 56) of cases in the registry; these were considered to be high volume centres (Supplementary Figure S1). Patient demographics and risk factors are provided in Table 1. There were 76 thoraco-abdominal aortic aneurysms (TAAAs) and 33 juxtapararenal aneurysms; of this last group, 11 were symptomatic or large aneurysms (33%).

A narrow aortic diameter $<$ 25 mm at the visceral aorta was present in 18 cases (15.5%). Other relevant anatomical details are provided in Table 2.

Procedural data

For E-nside advancement, femoral percutaneous access was obtained in 54% of patients; access for TV cannulation was the upper arm in 100 patients (86.2%), while contralateral femoral access was used in 16 (13.8%). The procedural details are provided in Table 3. A prior thoracic endograft was present in 15 patients (12.9%), while a proximal thoracic endograft plus E-nside were implanted in 52 (44.8%), with a 150 ± 8 mm mean aortic coverage above the coeliac trunk. Of the 52 adjunctive thoracic endografts implanted, 43 (83%) were deployed to extend proximally in type I — III thoracic aortic aneurysm (TAA), while in nine (17%) a thoracic endograft was used to fit the aortic diameter to the proximal E-nside diameter. The need for a proximal thoracic endovascular aortic repair (TEVAR) was more frequent for type I — III aneurysms than for type IV, pararenal, and juxtarenal aneurysms (75% *vs.* 19%; p $<$ .001). Sixty patients (51.7%) had a concomitant abdominal bi-iliac endograft implanted.

The branch related technical success rate was 98.7%. Of the 464 total TVs, 448 were successfully incorporated through a bridging stent (96.5%). Ten branches (2.1%) were intentionally occluded due to a pre-operative occlusion or

Table 1. Demographics and risk factors of the 116 patients in the ItaliaN Branched Registry of E-nside EnDograft (INBREED) registry treated with the E-nside endograft.

	Patients (n = 116)
Demographics	
Age — y	73.1±8.2
Male sex	76 (65.5)
Risk factors	
Body mass index — kg/m^2	27.1±4.1
Coronary artery disease	32 (27.6)
Chronic heart failure	9 (7.7)
Hypertension	103 (88.8)
Hypercholesterolaemia	76 (65.5)
Active or former smoker	64 (55.1)
Chronic obstructive pulmonary disease	49 (42.2)
Peripheral artery disease	17 (14.6)
Diabetes	12 (10.3)
Chronic kidney disease	22 (19.0)
Stroke or transient ischaemic attack	14 (12.1)

Data are presented as n (%) or mean ± standard deviation.

Table 2. Clinical and anatomical data of the 116 patients in the ItaliaN Branched Registry of E-nside EnDograft (INBREED) registry treated with the E-nside endograft.

	Patients (n = 116)
Clinical data	
Genetically triggered aortic disease	2 (1.7)
Prior open aortic repair	32 (27.6)
Prior EVAR	26 (22.4)
Type 1A endoleak after EVAR	11 (9.5)
Status of aortic disease	
Non-ruptured, asymptomatic	91 (78.4)
Non-ruptured, symptomatic	22 (19.0)
Contained or impending rupture	3 (2.6)
Anatomical data	
Aortic pathology	
Degenerative aneurysm	98 (84.5)
Post-dissection aneurysm	5 (4.3)
Subacute dissection	3 (2.6)
IMH/PAU	4 (3.4)
Pseudoaneurysm	6 (5.2)
Aneurysm extent[*]	
I	15 (13.8)
II	23 (21.1)
III	17 (15.6)
IV	21 (19.3)
Pararenal	29 (26.6)
Juxtarenal	4 (3.7)
Maximum aortic diameter − mm	66±17
Maximum diameter >80 mm	16 (13.8)
Visceral aortic diameter <25 mm	18 (15.5)
Visceral aortic diameter <30 mm	56 (48.3)
Minimum iliac access diameter − mm	8.7±1.4
Variables by target vessel	
Coeliac artery characteristics	
Stenosis > 50%	30 (25.9)
Pre-operative occlusion	5 (4.3)
Superior mesenteric artery characteristics	
Stenosis > 50%	7 (6.0)
Pre-operative occlusion	0 (0)
Right renal artery characteristics	
Stenosis > 50%	20 (17.2)
Pre-operative occlusion	2 (1.7)
Left renal artery characteristics	
Stenosis > 50%	13 (11.2)
Pre-operative occlusion	3 (2.6)

Data are presented as n (%) or mean ± standard deviation. EVAR = endovascular aortic repair; IMH = intramural haematoma; PAU = penetrating aortic ulcer.
* Includes degenerative aneurysms, dissecting aneurysms, pseudoaneurysms, and PAU.

Table 3. Procedural data of the 116 patients in the ItaliaN Branched Registry of E-nside EnDograft (INBREED) registry treated with the E-nside endograft.

	Patients (n = 116)
Vascular access for the main endograft	
Femoral, percutaneous	63 (54.3)
Femoral, surgical	45 (38.8)
Surgical iliac conduit	8 (6.9)
Vascular access for bridging branches	
Femoral, contralateral side	16 (13.8)
Upper arm, left side	72 (62.1)
Upper arm, right side	28 (24.1)
E-nside proximal diameter − mm	
33	44 (37.9)
38	72 (62.1)
E-nside distal diameter − mm	
26	91 (78.4)
30	25 (21.5)
Adjunctive proximal thoracic endograft	52 (44.8)
Prophylactic spinal drain	40 (34.5)
Procedural metrics	
Total operating time − min	240 (195–303)
Total contrast volume − mL	175 (120–235)
Total fluoroscopy time − min	87 (63–115)
Dose area product − Gy × cm^2	288 (179–885)
Endograft related technical success[*]	114 (98.3)
Variables by target vessel (n = 464)	
Target vessel related technical success[†]	458 (98.7)
Type of bridging stent	
Balloon expandable	360 (78.3)
Self expandable	88 (19.1)
Intentional branch occlusion	10 (2.2)
Unsuccessful target vessel cannulation	2 (0.4)
Bridging stent length − mm	
Coeliac artery	63.4±13.1
Superior mesenteric artery	66.0±9.9
Right renal artery	62.7±16.5
Left renal artery	62.0±16.0
Mean number of stents	
Coeliac artery	1.1±0.2
Superior mesenteric artery	1.1±0.2
Right renal artery	1.2±0.3
Left renal artery	1.2±0.3
Bridging time − min	
Coeliac artery	21.6±30.1
Superior mesenteric artery	18.5±19.8
Right renal artery	21.4±26.11
Left renal artery	24.6±37.7

Data are presented as n (%) or mean ± standard deviation.
* Endograft related technical success was defined as successful vascular access, delivery, and deployment of the main graft, with the absence of type I or type III endoleaks related to the main graft on completion angiography and patency of the modular aorto-iliac graft components.
† Branch related technical success was defined as successful catheterisation of intended target vessels, placement of bridging stents, absence of target vessel related endoleaks (type Ic, IIIb, and IIIc) on completion angiography, and patency of all intended side branch components.

tight stenosis of the TV, two vessels (0.4%) were not successfully cannulated, and intra-operative death occurred in one patient before bridging stent implantation; all 12 intentional occlusions of the inner branches were successful. Considering the 448 stented TVs, the main bridging stent was balloon expandable in 78% of cases and self expandable in 19%. The pre-loaded system was used in the majority of patients (n = 100; 86.2%) for branch cannulation, while in 16 cases (13.8%) it was voluntarily removed. Of the 400 branches with the pre-loaded system used on an intention to treat basis, an upper arm access was used to snare the guidewire in the majority of cases (n = 365; 91.2%), while snaring from the contralateral femoral access was performed for 29 (7.2%) branches. The pre-loaded system failed because of the unsuccessful advance of the 0.018 inch guidewire into the tube for the cuffs of six branches (1.5%) that were, in the end, cannulated independently.

The endograft related technical success rate was 98.2%. There were one unsuccessful E-nside deployment because of impossibility to advance through a severely diseased and small (< 7 mm) iliac access and one case of type Ia endoleak in a patient with proximal TEVAR owing to rapid proximal neck degeneration. The mean bridging time was 21.8 $\pm$ 28 minutes for each vessel, with no differences seen between those who had the pre-loaded system used and those who did not (22.3 $\pm$ 18 *vs.* 21.5 $\pm$ 21.1 minutes; $p = .86$). The total median duration of operation was 240 minutes (IQR 195, 303), the median duration of fluoroscopy was 87 minutes (IQR 63, 115), the median contrast volume was 175 mL (IQR 120, 235), and the median dose—area product was 288 Gy $\times$ cm^2 (IQR 179, 885)

Ninety day outcomes

The ninety day mortality rate was 5.2% ($n = 6$). One intra-operative death occurred in an elective case due to iliac artery rupture during an attempt to advance the endograft; after control of the bleeding was obtained, the patient died from cardiac complications. Four deaths occurred within 30 days (respiratory failure, $n = 2$; multi-organ failure, $n = 1$; haemorrhagic shock, $n = 1$), and one non-aortic related death occurred within 90 days. Of the six deaths, four occurred in patients treated in an urgent setting; therefore, the elective mortality rate was 2% ($n = 2/91$) and the urgent mortality rate was 16% ($n = 4/25$). Any MAE occurred in 24% of patients (acute kidney insufficiency, 8.6%; neurological complications, 10%; respiratory complications, 5% [Table 4]). Post-operative acute renal insufficiency occurred in 10 cases (five patients with pre-operative chronic kidney disease; three were treated urgently and two received intentional unilateral renal artery occlusion); no patient required dialysis. Neurological complications included four (3.4%) strokes (left arm access, 4.1%; right arm access, 3.6%; femoral access, 0% [$p = 1.0$]) and eight (6.9%) cases of SCI. SCI presented as a sensory deficit in three cases and a complete motor deficit in five; symptoms were permanent in four (3.4%) patients, while four (3.4%) experienced recovery of symptoms (two partial and two complete recoveries). Of the patients who experienced SCI, 75% had extent I — III, 25% were treated urgently, 25% had pre-operative unilateral occlusion of a hypogastric artery, and 25% had unilateral occlusion of a vertebral artery. The SCI rate was 6% in patients who had the pre-loaded system used in them *vs.* 12% for those who did not ($p = .29$).

Table 4. Ninety day outcomes of the 116 patients in the ItaliaN Branched Registry of E-nside EnDograft (INBREED) registry treated with the E-nside endograft.

	Patients ($n = 116$)
Medical outcomes	
Death	6 (5.2)
Duration of hospital stay — days	9 (5, 15)
Myocardial infarction	1 (0.9)
Heart failure	1 (0.9)
Respiratory failure	6 (5.2)
EBL > 1000 mL	4 (3.4)
Acute kidney insufficiency	10 (8.6)
Stroke or transient ischaemic attack	4 (3.4)
Spinal cord ischaemia	8 (6.9)
Permanent	4 (3.4)
Temporary	4 (3.4)
Gastrointestinal complications	1 (0.9)
Surgical outcomes	
Lower limb ischaemia	0 (0)
Re-intervention	10 (8.6)
Vascular access	5 (4.3)
Target vessel	4 (3.4)
Main endograft	1 (0.9)
Variables by target vessel (n = 448)	
Freedom from branch instability	436 (97.3)
Freedom from type I — III endoleaks	447 (99.8)
Primary patency	437 (97.5)

Data are presented as *n* (%) or median (interquartile range). EBL = estimated blood loss

Within 90 days, there was one (0.9%) re-intervention for type Ia endoleak, five (4.3%) re-interventions for access complications, and four (3.4%) re-interventions for TV complications. Freedom from TV instability was 97.3%; there was one type Ic endoleak, and nine occlusions or stenoses requiring re-intervention. Branch technical success (99% *vs.* 99%; $p = 1.0$) and instability (3.3% *vs.* 2.7%; $p = .68$) rates were similar between those with a visceral aortic diameter < 25 mm and those with a visceral aortic diameter ≥ 25 mm.

In the subgroup with degenerative aneurysms, the technical success rate was 97%, the 90 day mortality rate was 4%, the freedom from TV instability rate was 97%, and any MAE occurred in 23% of patients. Compared with patients receiving a primary aortic treatment, patients with a prior aortic repair had a higher contrast volume (249 $\pm$ 131 mL *vs.* 171 $\pm$ 133 mL; $p = .017$); technical success (97.9% *vs.* 95.4%; $p = .47$) and mortality (2.1% *vs.* 6.3%; $p = .29$) rates were similar. Comparing outcomes between high and low volume centres, there was a trend toward the treatment of more complex cases in high volume centres (prior endovascular treatment 25% *vs.* 20% [$p = .65$]; TAA extent I — III 50% *vs.* 25% [$p = .007$]). Technical success (98% *vs.* 98%; $p = .99$), procedural metrics (duration of operation 250 [IQR 207, 307] *vs.* 255 [IQR 198, 332] minutes [$p = .084$]; contrast volume 120 [IQR 98, 180] *vs.* 200 [IQR 142, 250] mL [$p = .004$]; duration of fluoroscopy 97 [IQR 73, 118] *vs.* 102 [IQR 63, 137] minutes [$p = .59$]; radiation dose 267 [IQR 185, 798] *vs.* 346 [IQR 201, 1005] Gy $\times$ cm^2 [$p = .078$]), mortality rate (2% *vs.* 6.6%; $p = .26$), and any MAE (23.9% *vs.* 25.5%; $p = .85$) were not statistically significantly different.

DISCUSSION

In this multicentre study, 116 patients treated with an E-nside for a wide spectrum of disease extent and aetiology, both in elective and urgent settings, were enrolled. Regarding elective cases, this off the shelf device may fit different aortic anatomies thanks to its four geometric configurations, even if custom made devices still play a major role. In this series, 78% of cases were elective; of these, 50% had prior aortic repair

and 60% were had extent I — IV TAAAs. These data may suggest that many of these cases, even if not urgent, were considered by the operator as high risk for rupture, with an indication for rapid aneurysm exclusion. The proportion of elective cases in this study was similar (63% elective) to the experience reported with another off the shelf device (Zenith T branch; Cook Medical).[17] Regarding disease extent, E-nside use, in cases with juxta- or pararenal aneurysm, needs to be carefully weighed with the option of a dedicated custom device, in terms of waiting time *vs.* risk of SCI. It is believed that a readily available off the shelf device is justified in a subset of patients at high rupture risk, or with symptomatic or ruptured aneurysms.[17] In the present cohort, the E-nside technical success rate was high (98.2%), with a type I or III endoleak rate of 1.8%; there were no open conversions, with acceptable early re-intervention (8.6%) and mortality (5.1%) rates. Branch related outcomes were also satisfactory, with a 97.3% freedom from TV instability at 90 days. These results are in line with the experience of the Zenith T branch (Cook Medical) reported by Kölbel *et al.* in 2021.[17] The authors reported an overall technical success rate of 97%, with an elective 30 day mortality rate of 8.5%, a primary branch patency rate of $>$ 99%, and a 2.7% rate of type I and III endoleak. This indirect comparison suggests that the E-nside endograft is safe and effective. Also, looking at urgent and emergency cases, the early mortality rate reported in this registry (12%) is similar to that of a T-branch series of 65 cases reported by Gallitto *et al.* (14%),[6] and to that of a series of 100 patients reported by Eleshra *et al.* (15%).[18]

Some structural characteristics of the E-nside should be considered when comparing the results to the T-branch, as they may facilitate the procedure and positively influence technical success.

A key aspect to be considered is the position of the inner branch outlets, located in the 24 mm diameter main graft portion. The suggested minimum aortic lumen diameter in the visceral segment is $\geq$ 24 mm for the E-nside and $\geq$ 25 mm for the T-Branch, based on information from the manufacturer or from reported data, but this is not clearly specified in the IFU.[11,12] In particular, the inner branch configuration may be helpful in facilitating adequate cuff opening in cases with a narrow aorta or dissections with a narrow true lumen.[7,19] In the INBREED registry, 15% of cases had a lumen $<$ 25 mm, and no differences in terms of technical success and branch stability were recorded in comparing these cases with those with a larger lumen.

Pre-cannulation allows not only for obtaining rapid branch access, but is also useful in facilitating TV cannulation owing to the presence of a stable through and through wire in the branch, especially in cases of tortuous or narrow aorta.[20] The advantages of pre-loaded branches have already been described by Mirza *et al.*,[21] where 30 novel custom pre-loaded low profile Cook devices were used and improved the reported procedural metrics when compared with a standard T-Branch. In the present experience, the bridging time did not differ significantly between cases in which the pre-loaded system was used and those in which it was not; however, this comparison was limited by the low number of cases who did not have the pre-loaded system used in them (13.8%).

A possible drawback of the pre-loaded system is the manipulation required for guidewire snaring from the upper extremity; to avoid the risk of peri-operative stroke, pre-loaded guidewires should be snared in the descending thoracic aorta and not in the arch or ascending aorta. In the present experience, the stroke rate was similar to that reported by Kölbel *et al.*, who used the Cook T-Branch (3.4% *vs.* 2.5%).[17] All neurological events occurred in cases of upper extremity access (4.2%), while no cases of stroke were reported when pre-cannulation snaring was obtained via the femoral access. This is in line with the experience of Timaran *et al.*,[22] where the reported stroke rate was 2.3% in cases of upper access and 0% in femoral access cases in patients receiving a pre-cannulated endograft. Similar results were also achieved by Eilenberg *et al.* in a series of 152 branched endografts.[23]

The SCI rate was acceptable and comparable to the experience of Kölbel *et al.* (7.2% *vs.* 10.5%).[17] A standard E-nside repair requires the delivery system to be kept in place for the entire duration of graft deployment and vessel bridging; during this time the ipsilateral hypogastric artery may be hypoperfused or temporarily occluded. This is probably the reason why, in selected cases, some operators prefer to remove the pre-cannulation sheath voluntarily and deploy the entire endograft, and immediately removing the delivery system, allowing for rapid hypogastric and lower limb artery re-perfusion. In these cases, aneurysm exclusion is obtained with standard branch cuff cannulation, taking advantage of the sole inner branch concept. Therefore, the operator has to balance the advantage of a pre-loaded system with the risks of delayed hypogastric re-perfusion on a case by case basis, evaluating the extent of coverage, contralateral hypogastric and left subclavian artery status, and time needed to complete the four vessel bridging.

The feasibility of the E-nside endograft has been evaluated theoretically by Bilman *et al.*,[12] who concluded that the device can be used in half of TAAA cases and that the primary limitation is the 24 F outer diameter sheath. The T-branch also has a 24 F outer diameter introducer sheath, but it lacks a pre-cannulation system; there do not seem to be great differences between the two endografts in terms of access related complications (E-nside 4.3% *vs.* T-Branch 7.7%).[17] The IFU of the E-nside suggest landing proximally in a thoracic endograft. In the INBREED registry, when an adequate proximal sealing length was present, implantation was done in the native thoracic aorta with no proximal extension, with the aim of reducing the possible length of coverage as much as possible. The endograft has no proximal active fixation (intended as barbs or free flow); however, no cases of intra-operative migration have been reported, as there were no cases of infolding, distal migration, or inadequate sealing at 90 days after landing in the native aorta.

The INBREED registry included both high volume and low volume centres with different grades of experience, with a trend toward more complex cases in the high volume group. Even if a comparison between these two groups did not show a statistically significant difference in technical success

rates, MAEs, and mortality, the results may have been biased by the small number of events.

This study had some limitations. The procedure was not standardised between the different centres, and the device has only been available on the market for a few months; therefore, the eventual learning curve phase was included in the analysed experience.

Conclusion

This is the first real life, non-sponsored registry of E-nside endografts used for the treatment of a broad spectrum of aortic pathologies, including urgent and or complex anatomy. The results demonstrated technical implantation safety and efficacy; however, confirmatory studies are needed to evaluate longer term results.

CONFLICTS OF INTEREST

M.P.: consulting agreement; all consulting fees paid to the Department of Cardiac Thoracic Vascular Sciences and Public Health, University of Padua. G.S.: consulting agreement, travel grant, proctor. G.Pr.: fee for employ tutoring. P.F.: advisory board. M.A.: consulting agreement, travel grant; all fees paid to the Department of Cardiac Thoracic Vascular Sciences and Public Health, University of Padua. The other authors have no conflicts of interest to declare.

FUNDING

None.

APPENDIX A. SUPPLEMENTARY DATA

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ejvs.2023.02.076

REFERENCES

1 Cowan JA, Dimick JB, Henke PK, Huber TS, Stanley JC, Upchurch GR. Surgical treatment of intact thoracoabdominal aortic aneurysms in the United States: hospital and surgeon volume-related outcomes. *J Vasc Surg* 2003;**37**:1169–74.
2 Oderich GS, Tenorio ER, Mendes BC, Lima GBB, Marcondes GB, Saqib N, et al. Midterm outcomes of a prospective, nonrandomized study to evaluate endovascular repair of complex aortic aneurysms using fenestrated-branched endografts. *Ann Surg* 2021;**274**:491–9.
3 Riambau V, Böckler D, Brunkwall J, Cao P, Chiesa R, Coppi G, et al. Editor's Choice – Management of descending thoracic aorta diseases. *Eur J Vasc Endovasc Surg* 2017;**53**:4–52.
4 Sweet MP, Hiramoto JS, Park KH, Reilly LM, Chuter TAM. A standardized multi-branched thoracoabdominal stent-graft for endovascular aneurysm repair. *J Endovasc Ther* 2009;**16**:359–64.
5 Bosiers M, Kölbel T, Resch T, Tsilimparis N, Torsello G, Austermann M. Early and midterm results from a postmarket observational study of Zenith t-Branch thoracoabdominal endovascular graft. *J Vasc Surg* 2021;**74**:1081–9.
6 Gallitto E, Faggioli G, Spath P, Pini R, Mascoli C, Logiacco A, et al. Urgent endovascular repair of thoracoabdominal aneurysms using an off-the-shelf multibranched endograft. *Eur J Cardiothorac Surg* 2022;**61**:1087–96.
7 Ferrer C, Orrico M, Spataro C, Coscarella C, Ronchey S, Marino M, et al. Outcomes of multibranched off-the-shelf stent graft in elective and urgent/emergent repair of complex aortic aneurysms with narrow internal aortic lumen. *J Vasc Surg* 2022;**76**:326–34.
8 Gallitto E, Gargiulo M, Freyrie A, Pini R, Mascoli C, Ancetti S, et al. Off-the-shelf multibranched endograft for urgent endovascular repair of thoracoabdominal aortic aneurysms. *J Vasc Surg* 2017;**66**:696–704.
9 Spanos K, Kölbel T, Theodorakopoulou M, Heidemann F, Rohlffs F, Debus ES, et al. Early outcomes of the t-Branch off-the-shelf multibranched stent-graft in urgent thoracoabdominal aortic aneurysm repair. *J Endovasc Ther* 2018;**25**:31–9.
10 Simonte G, Isernia G, Gatta E, Neri E, Parlani G, Candeloro L, et al. Inner branched complex aortic repair outcomes from a national multicenter registry using the E-xtra design platform. *J Vasc Surg* 2023;**77**:338–46.
11 Bertoglio L, Grandi A, Carta N, Cambiaghi T, Bilman V, Melissano G, et al. Comparison of anatomic feasibility of three different multibranched off-the-shelf stent-grafts designed for thoracoabdominal aortic aneurysms. *J Vasc Surg* 2021;**74**:1472–82.
12 Bilman V, Cambiaghi T, Grandi A, Carta N, Melissano G, Chiesa R, et al. Anatomical feasibility of a new off-the-shelf inner branch stent graft (E-nside) for endovascular treatment of thoracoabdominal aneurysms. *Eur J Cardiothorac Surg* 2020;**58**:1296–303.
13 Zimmermann A, Menges AL, Rancic Z, Meuli L, Dueppers P, Reutersberg B. E-nside off-the-shelf inner branch stent graft: technical aspects of planning and implantation. *J Endovasc Ther* 2022;**29**:167–74.
14 Piazza M, Pratesi G, Tshomba Y, Gaggiano A, Carbonari L, Simonte G, et al. Early outcomes of a novel off-the-shelf preloaded inner branch endograft for the treatment of complex aortic pathologies in the ItaliaN Branched Registry of E-nside EnDograft (INBREED). *J Vasc Surg* 2022;**75**:e332–3.
15 Harris PA, Taylor R, Thielke R, Payne J, Gonzalez N, Conde JG. Research electronic data capture (REDCap) – a metadata-driven methodology and workflow process for providing translational research informatics support. *J Biomed Inform* 2009;**42**:377–81.
16 Oderich GS, Forbes TL, Chaer R, Davies MG, Lindsay TF, Mastracci T, et al. Reporting standards for endovascular aortic repair of aneurysms involving the renal-mesenteric arteries. *J Vasc Surg* 2021;**73**(1S):4S–52S.
17 Kölbel T, Spanos K, Jama K, Behrendt CA, Panuccio G, Eleshra A, et al. Early outcomes of the t-Branch off-the-shelf multi-branched stent graft in 542 patients for elective and urgent aortic pathologies: a retrospective observational study. *J Vasc Surg* 2021;**74**:1817–24.
18 Eleshra A, Hatm M, Spanos K, Panuccio G, Rohlffs F, Debus ES, et al. Early outcomes of t-Branch off-the-shelf multibranched stent graft in urgent and emergent repair of thoracoabdominal aortic aneurysms. *J Vasc Surg* 2022;**75**:416–24.
19 Squizzato F, Antonello M, Forcella E, Coppadoro S, Colacchio C, Xodo A, et al. Geometrical determinants of target vessel instability in fenestrated endovascular aortic repair. *J Vasc Surg* 2022;**76**:335–43.
20 Squizzato F, Oderich GS, Balachandran P, Tenorio ER, Mendes BC, de Martino RR. Effect of aortic angulation on the outcomes of fenestrated-branched endovascular aortic repair. *J Vasc Surg* 2021;**74**:372–82.
21 Mirza AK, Tenorio ER, Kärkkäinen JM, Pather K, Kratzberg J, Mendes BC, et al. Outcomes of a novel upper extremity preloaded delivery system for fenestrated-branched endovascular repair of thoracoabdominal aneurysms. *J Vasc Surg* 2020;**72**:470–9.
22 Timaran CH, Oderich GS, Tenorio ER, Farber MA, Schneider DB, Schanzer A, et al. Expanded use of preloaded branched and fenestrated endografts for endovascular repair of complex aortic aneurysms. *Eur J Vasc Endovasc Surg* 2021;**61**:219–26.
23 Eilenberg W, Kölbel T, Rohlffs F, Oderich G, Eleshra A, Tsilimparis N, et al. Comparison of transfemoral versus upper extremity access to antegrade branches in branched endovascular aortic repair. *J Vasc Surg* 2021;**73**:1498–503.